

Knocks out of the 1.
but no swarthy etc.

(12) **UK Patent Application** (19) **GB** (11) **2 356 439** (13) **A**

(43) Date of A Publication 23.05.2001

(21) Application No 9923000.5

(22) Date of Filing 29.09.1999

(71) Applicant(s)

University of Durham
(Incorporated in the United Kingdom)
Old Shire Hall, Old Elvet, DURHAM, DH1 3HP,
United Kingdom

(72) Inventor(s)

Ernest Appleton
Neil William Stutchbury

(74) Agent and/or Address for Service

Urquhart-Dykes & Lord
St Nicholas Chambers, Amen Corner,
NEWCASTLE-UPON-TYNE, NE1 1PE, United Kingdom

(51) INT CL⁷

F16L 55/34

(52) UK CL (Edition S)

F2P PG1
B7H HNF

(56) Documents Cited

GB 2350386 A **GB 2333341 A** **GB 2305407 A**
GB 2167829 A **GB 0614592 A**

(58) Field of Search

UK CL (Edition S) **B7H HNF** , **E1F FHJ FKU** , **F2N** , **F2P**
PG1

INT CL⁷ **B08B 9/04** , **F16L 55/30** **55/32** **55/34** **55/36**
55/38

Online: **WPI** , **EPODOC** , **JAPIO**

(54) Abstract Title

Conduit traversing vehicle

(57) A vehicle 1 for travelling along a conduit 2 having fluid flowing therein is described. The vehicle comprises a forward set of surface engaging means, resilient bristles 12, and a rear set of surface engaging means, preferably bristles 18, which are adapted to move towards and away from the forward bristles 12. The forward bristles 12 engage the surface of the conduit 2 and apply a greater gripping force when they are moving towards the rear bristles 18 than when they are moving away from the rear bristles 18. Similarly, the rear bristles 18 apply a larger gripping force to the surface of the conduit 2 when they are moving away from the forward bristles 12 than when they are moving towards the forward bristles 12. A drive means 4 has a shaft 9 which is rotated by fluid flow, and a reverse traverse screw 14 is preferably connected to the shaft such that rotation of the shaft 9 causes a thread follower 16 to move along the reverse traverse screw 14 first in one direction, and then the other, to move the forward 12 and rear 18 bristles towards and then away from each other. This causes the vehicle 1 to move along the conduit 2.

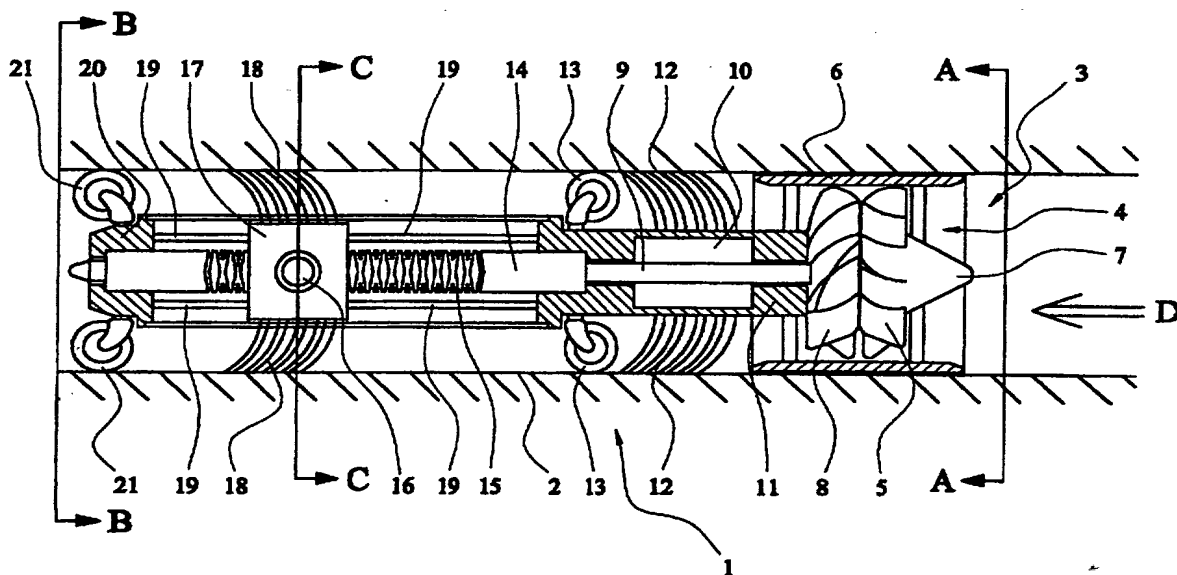


FIG. 1

-1/4-

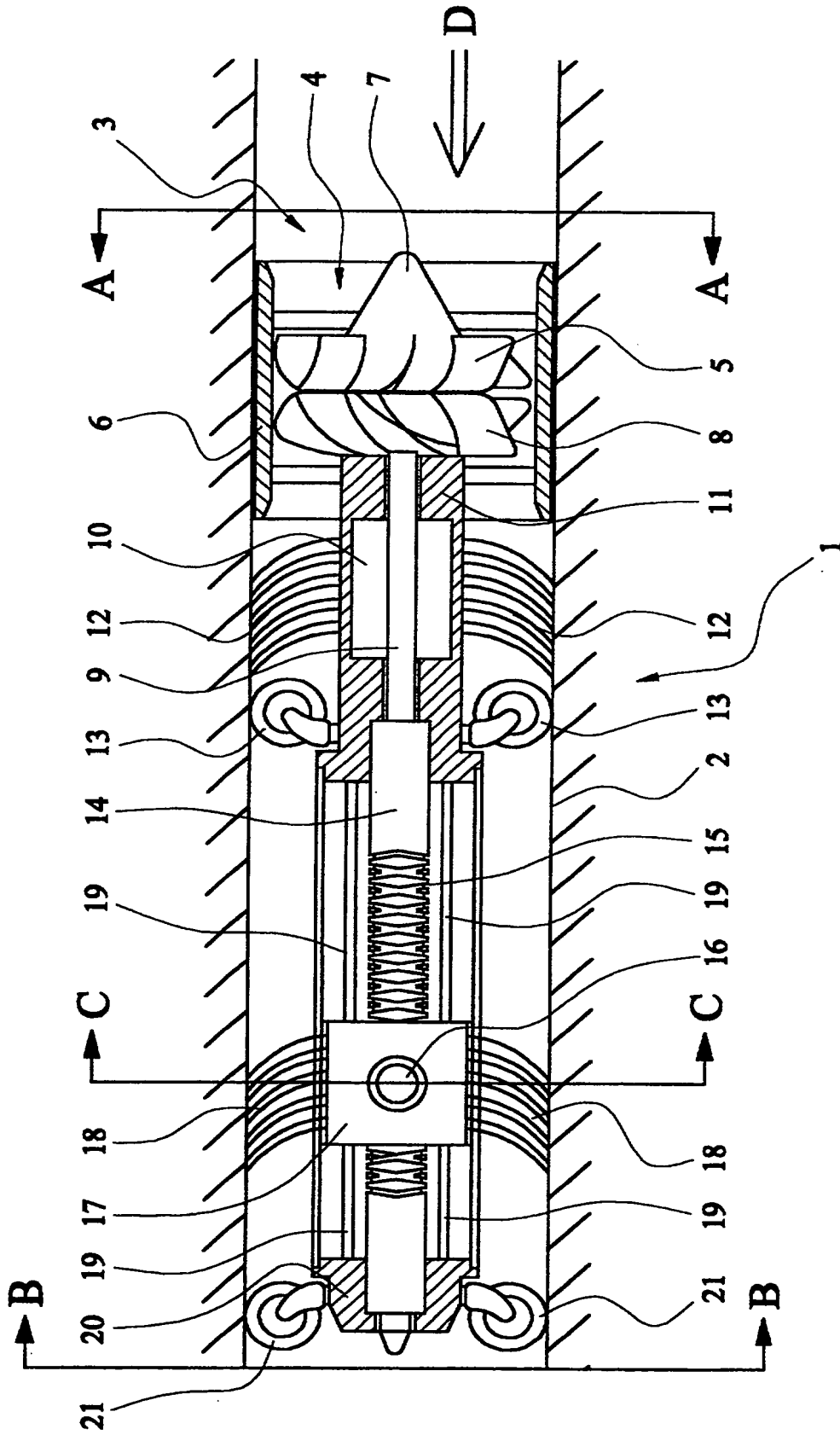


FIG. 1

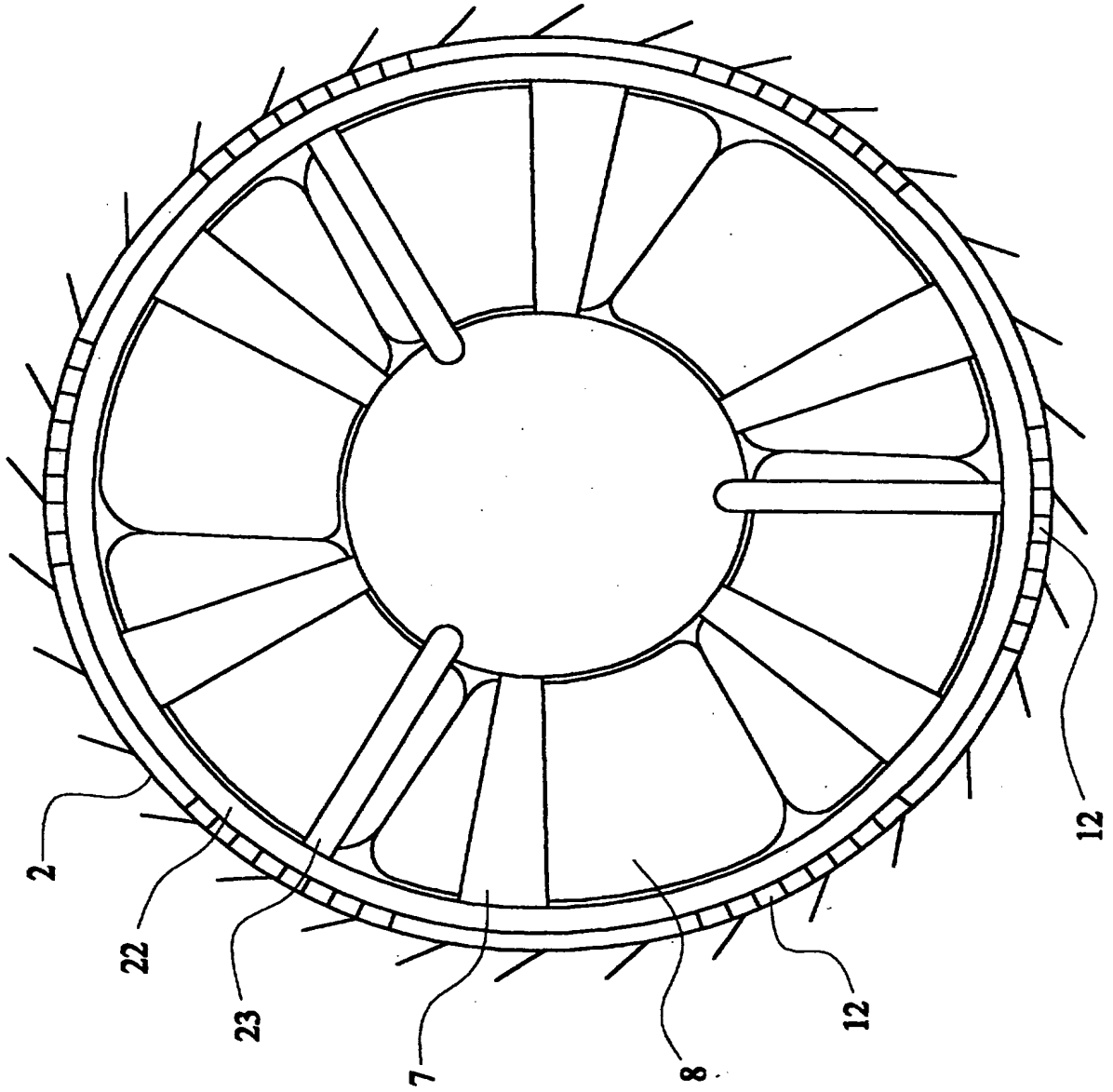


FIG. 2

-3/4-

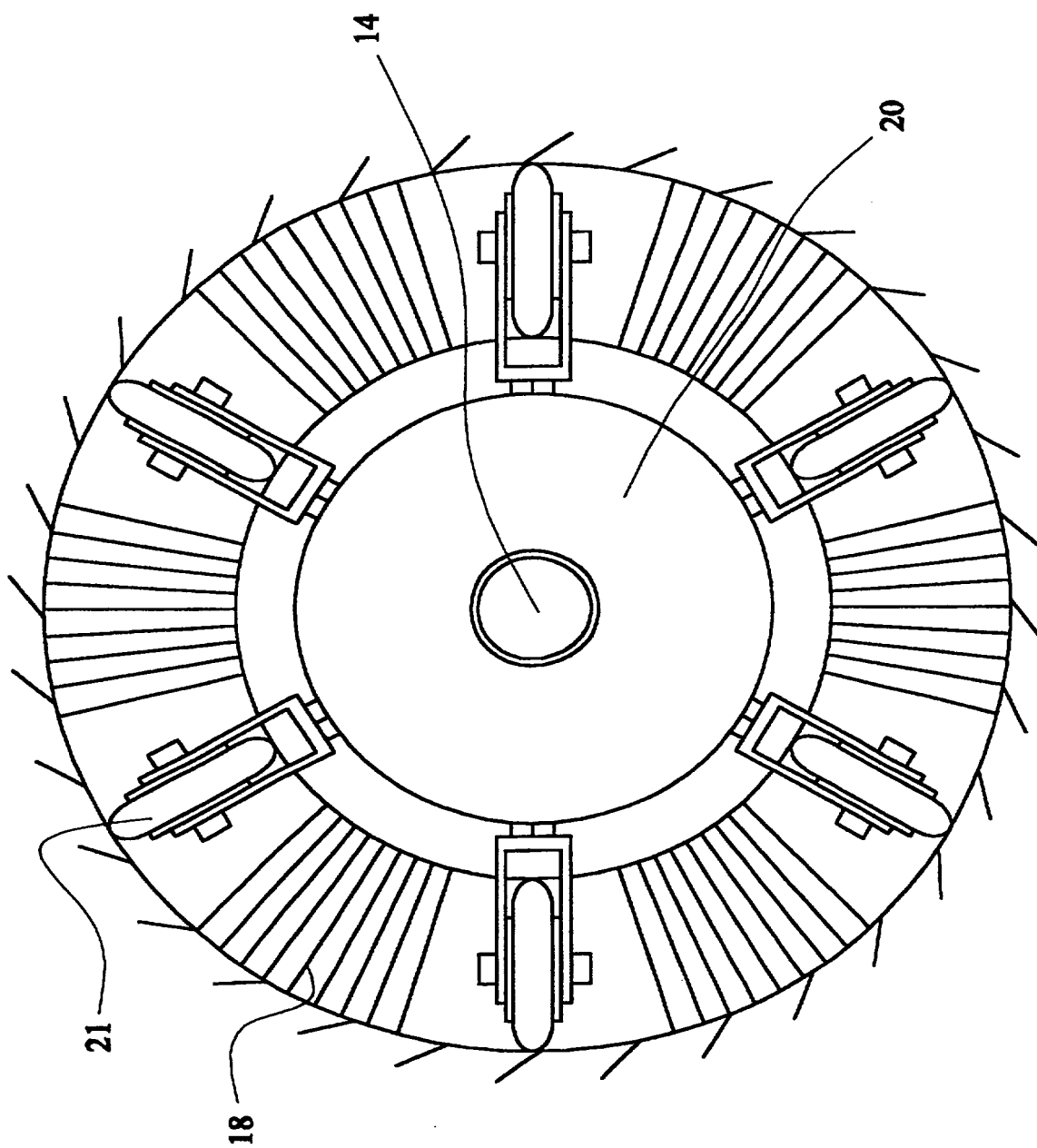


FIG. 3

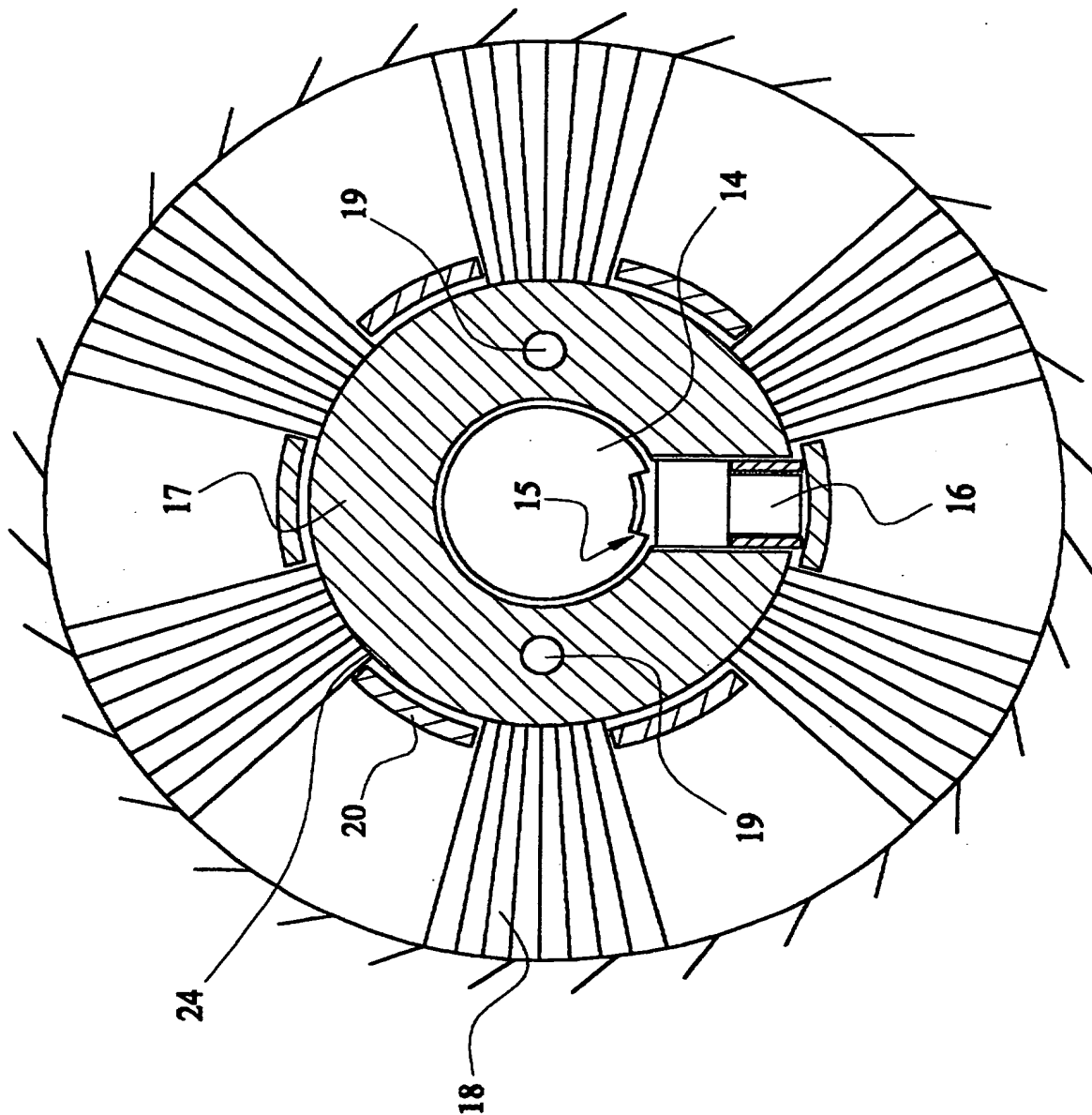


FIG. 4

CONDUIT TRAVERSING VEHICLE

The present invention relates to vehicles for travelling along conduits having fluid flowing therein, and relates particularly, but not exclusively, to vehicles for travelling along liquid transportation pipelines having liquid flowing therein.

In many industries, it is important to be able to gain access to pipelines for maintenance and/or inspection. Pipeline inspection vehicles are known which engage the internal surface of a pipeline and propel themselves along the pipeline, deriving power from a remote power source connected to the vehicle by means of an umbilical cable.

Such known pipeline inspection vehicles are generally only used for pipelines in which no fluid is flowing and if the distance to be travelled is relatively short (up to 1km). If fluid is present and flowing it is possible to use a pig which uses the pressure of the fluid acting over sealing cups to propel the vehicle forward, that is, with the flow of the fluid. However, most conventional pigs are only uni-directional and, as such, must be recovered via a pig receiving trap at the opposite end of the pipeline. If a pig receiving trap is not fitted, which is often the case, then it is desirable to have a bi-directional vehicle. Such long range bi-directional vehicles do not presently exist. As a result of this drawback, it is usually necessary to suspend operation of the pipeline for the duration of the vehicle operation. In the case of industries such as the oil or petroleum industry, ceasing operation of a pipeline for the duration of a maintenance and/or inspection operation can involve unacceptably high cost.

Preferred embodiments of the present invention seek to overcome the above disadvantages of the prior art.

According to the present invention, there is provided a vehicle

for travelling along a conduit having fluid flowing therein, the vehicle comprising:

- (a) propulsion means including first surface engaging means for engaging a surface of the conduit to apply a gripping force thereto, and at least one second surface engaging means located forwardly in use of said first surface engaging means and adapted to engage a surface of the conduit to apply a gripping force thereto and adapted to move towards and away from said first surface engaging means, wherein the or each said second surface engaging means in use applies a greater gripping force when it is moving towards said first surface engaging means than when it is moving away from said first surface engaging means, and said first surface engaging means applies a larger gripping force when it is moving away from the or each said second surface engaging means than when it is moving towards the or each said second surface engaging means, to cause said propulsion means to move along the conduit;
- (b) drive means having a shaft portion adapted to be rotated as a result of fluid flow relative to the drive means; and
- (c) connector means for causing the or each said second surface engaging means to move away from said first surface engaging means as a result of rotation of said shaft portion.

The present invention is based on the surprising discovery that sufficient energy can be generated from the fluid flow relative to the vehicle to propel the vehicle along the conduit in the opposite direction to the direction of fluid flow. This provides the advantage that the vehicle can under certain circumstances access previously inaccessible conduits, and can crawl "outwards" from a launching point against the flow of

fluid and swim back an almost infinite distance to its launching point with the flow of fluid, and transport of fluid along the conduit does not need to be suspended while the vehicle is in operation. In the case of the oil and petroleum industries, this avoids the unacceptably high cost of shutting a pipeline down.

Preferably, said first and/or second surface engaging means comprises a respective plurality of resilient bristles.

By providing bristles such that the external diameter of the vehicle at the bristles is greater than the internal diameter of the conduit, the bristles can engage the internal surface of the conduit oriented in the opposite direction to the direction of travel of the vehicle. This enables the frictional force between the bristles and the conduit to be greater in one direction than in the other. This provides the further advantage that no further energy input is required to cause the bristles to apply a gripping force to the surface of the conduit, and enables the propulsion means to be constructed in a simple and cost effective manner.

Alternatively, the first and/or second surface engaging means may comprise a respective electrically and/or magnetically operated gripping means.

In a preferred embodiment, said first and/or second surface engaging means is mounted to a respective vehicle body portion and adjacent pairs of said body portions are adapted to move relative to each other.

In an alternative embodiment, said first and/or second surface engaging means is mounted to a single vehicle body portion.

The drive means may comprise at least one turbine.

At least one said turbine may be a multi stage turbine.

This provides the advantage of increasing the efficiency with which rotational energy of the shaft portion is derived from fluid flow relative to the drive means.

The drive means preferably further comprises at least one stator for altering direction of fluid flow to increase efficiency of transfer of energy from the fluid to at least one said turbine.

For example, the or each said stator may alter the direction of fluid flow to maximise the extent to which fluid contacts blades of at least one said turbine substantially perpendicularly to the face of the blades to maximise efficiency of energy transfer.

In a preferred embodiment, said connector means comprises a first part having at least one first cam groove and a second part having at least one cam projection adapted to engage at least one said first cam groove such that rotation of said shaft portion in a first sense causes at least one said cam projection to move along a said first cam groove to cause at least one said second surface engaging means to move away from said first surface engaging means.

This feature is based on the highly surprising discovery that contrary to expectations, by providing a first part having at least one first cam groove and a second part having at least one cam projection, sufficient energy can be derived from rotation of the shaft portion to cause at least one said second surface engaging means to move away from the first surface engaging means.

The first part may further include at least one second cam groove to cause at least one said second surface engaging means to move towards said first surface engaging means.

In a preferred embodiment, the or each said first cam groove

has a smaller pitch than the or each said second cam groove.

Since movement of the or each said second surface engaging means away from said first surface engaging means requires more energy than movement towards said first surface engaging means (because movement of the first and second surface engaging means away from each other generally involves moving the second surface engaging means, drive means and connector means against the flow of fluid, whereas movement of the surface engaging means together generally only involves movement of the first surface engaging means against the flow of fluid), by providing the or each said second cam groove of larger pitch than the or each said first cam groove, this provides the advantage of enabling the or each second surface engaging means to be moved towards the first surface engaging means as rapidly as possible.

In a preferred embodiment, at least one said first cam groove is connected to at least one said second cam groove, and at least one said cam projection is adapted to transfer between said first and second cam grooves to reverse the direction of travel of the first part relative to the second part.

The vehicle may further comprise biasing means for urging at least one said second surface engaging means towards said first surface engaging means.

This provides the advantage that the propulsion means can under certain circumstances be constructed in a relatively simple manner, without the need for the connector means to cause the or each second surface engaging means to move towards said first surface engaging means.

| The vehicle may further comprise at least one gearbox connected between said drive means and said connector means.

This provides the advantage of giving a mechanical advantage

which enables the vehicle to travel more efficiently along the conduit.

In a preferred embodiment, the vehicle is articulated.

This provides the advantage of enabling the vehicle to negotiate bends in the conduit.

The vehicle is preferably articulated rearwardly of said drive means in use.

The vehicle preferably further comprises braking means for increasing the fluid drag of the vehicle.

This provides the advantage of enabling the vehicle to travel with the flow of fluid along the conduit when the vehicle is to be recovered from the conduit.

The braking means preferably comprises at least one sealing means for sealingly engaging the internal surface of the conduit.

The vehicle may further comprise one or more wheels for engaging the surface of the conduit.

The vehicle may further comprise conduit inspection means.

The vehicle may further comprise conduit repair means.

As an aid to understanding the invention, a preferred embodiment thereof will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:-

Figure 1 is a partial longitudinal cross-sectional view of a conduit traversing vehicle embodying the present invention:

Figure 2 is a view along the line A-A in Figure 1;

Figure 3 is a view along the line B-B in Figure 1; and

Figure 4 is a view along the line C-C in Figure 1.

Referring in detail to Figure 1, a vehicle 1 for travelling along a conduit 2 such as a pipeline having a fluid 3 such as oil flowing therein in the direction of arrow D comprises a drive means 4 including a turbine 5 located within a housing 6. The turbine 5 has a stator 7 (the function of which will be described below) and a rotor 8 connected to a shaft 9 via a gearbox 10 such that movement of fluid 3 in the direction of arrow D causes rotation of the rotor 8 which in turn causes rotation of the shaft 9.

A first body member 11 is connected to the drive means 4 such that the shaft 9 can rotate relative to the body member 11. The body member 11 carries a first set of resilient bristles 12 having an external diameter greater than the internal diameter of the conduit 2 so that the bristles 12 engage the internal surface of the pipeline 2 and point in the direction of arrow D. The body member 11 also carries a set of wheels 13 for engaging the internal surface of the conduit 2 and centralising the vehicle 1 within the conduit.

A reverse traverse screw 14 is connected to the shaft 9 and has two sets of cam grooves 15 in its surface which mate with a thread follower 16 supported by a nut 17 carrying a second set of resilient bristles 18 of similar construction to the first set of bristles 12. The nut 17 is mounted to a guide 19 which is in turn connected to a housing 20 carrying the end of reverse traverse screw 14 remote from the drive means 4. Rotation of the shaft 9 causes rotation of reverse traverse screw 14 which, through engagement of the thread follower 16 in cam grooves 15, causes axial movement of the nut 17 along guides 19 relative to the body member 11. The housing 20

contains a bearing, and is provided with a set of wheels 21 for engaging the internal surface of the pipeline 2.

Referring in detail to Figure 2, the turbine housing 6 comprises a cowling 22 supporting the stator 7 on struts 23, the cowling 22 being sized to have a small clearance from the internal wall of the conduit 2. The rotor 8 is arranged behind the stator 7 and the surfaces of the rotor and stator are oriented such that the stator 7 causes the direction of fluid flowing therethrough to change so that the fluid contacts the blades of the rotor 8 in a direction generally perpendicular to the faces of the blades to ensure maximum efficiency of energy transfer.

Referring to Figure 3, the reverse traverse screw 14 having cam grooves 15 is received within housing 20 supporting wheels 21 which in turn engage the internal surface of the conduit 2. The wheels 21 and rear bristles 18 are alternately spaced circumferentially around the axis of the vehicle.

Figure 4 shows a cross-sectional view along the line C-C in Figure 1. The nut 17 carries thread follower 16 which engages one of the grooves 15 on the reverse traverse screw 14, and the nut 17 is adapted to slide along guides 19 located within the housing 20. The bristles 18 project through elongate slots 24 in the housing 20.

The operation of the vehicle 1 described with reference to Figures 1 to 4 will now be described.

As fluid flows in the direction of arrow D shown in Figure 1, movement of the fluid through the stator 7 causes the turbine rotor 8 to rotate, which in turn causes rotation of the shaft 9. This in turn causes rotation of the reverse traverse screw 14, as a result of which the thread follower 16 engages a first one of the cam grooves 15 and causes the nut 17 to slide longitudinally relative to the body member 11. This causes

the first bristles 12 and second bristles 18 to be moved away from each other.

Because the bristles 12, 18 are oriented backwards relative to the direction of travel of the vehicle, the frictional force of the bristles 12, 18 against the wall of the pipe 2 is greater in the rearward direction than in the forward direction. Accordingly, the rear bristles 18 do not move or move very little relative to the wall of the conduit 2, whereas the forward bristles 12 and body member 11 are urged forwards.

As the nut 17 reaches the end of its travel along the cam groove 15 of the reverse traverse screw 14, the thread follower 16 is so shaped that it is forced to engage the other cam groove 15 and is caused to move in the opposition direction relative to the reverse traverse screw 14. As a result, the rear bristles 18 and front bristles 12 are moved towards each other. The forward bristles 12 have greater resistance to moving backwards than the rear bristles 18 have to moving forwards, so the forward bristles 12 and body member 11 remain stationary, or only move very little, relative to the pipe wall 2 and the rear bristles 18 are moved forwards until the nut 17 reaches the forward end of its travel along the reverse traverse screw 14. The process then repeats itself, and the vehicle 1 travels along the pipe 2.

It will be appreciated by persons skilled in the art that the above embodiment has been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims. For example, more than two sets of bristles 12,18 may be used, or the bristles may be replaced by elongate elastomeric members. Alternatively, the bristles 12,18 may be replaced by electrically or magnetically operated gripping means which are urged radially outwards from the vehicle body to apply a gripping force to the internal wall of the conduit.

CLAIMS

1. A vehicle for travelling along a conduit having fluid flowing therein, the vehicle comprising:

- (a) propulsion means including first surface engaging means for engaging a surface of the conduit to apply a gripping force thereto, and at least one second surface engaging means located forwardly in use of said first surface engaging means and adapted to engage a surface of the conduit to apply a gripping force thereto and adapted to move towards and away from said first surface engaging means, wherein the or each said second surface engaging means in use applies a greater gripping force when it is moving towards said first surface engaging means than when it is moving away from said first surface engaging means, and said first surface engaging means applies a larger gripping force when it is moving away from the or each said second surface engaging means than when it is moving towards the or each said second surface engaging means, to cause said propulsion means to move along the conduit;
- (b) drive means having a shaft portion adapted to be rotated as a result of fluid flow relative to the drive means; and
- (c) connector means for causing the or each said second surface engaging means to move away from said first surface engaging means as a result of rotation of said shaft portion.

2. A vehicle according to claim 1, wherein said first and/or second surface engaging means comprises a respective plurality of resilient bristles.

3. A vehicle according to claim 1, wherein the first and/or second surface engaging means comprises a respective

electrically and/or magnetically operated gripping means.

4. A vehicle according to any one of the preceding claims, wherein said first and/or second surface engaging means is mounted to a respective vehicle body portion and adjacent pairs of said body portions are adapted to move relative to each other.

5. A vehicle according to any one of claims 1 to 3, wherein said first and/or second surface engaging means is mounted to a single vehicle body portion.

6. A vehicle according to any one of the preceding claims, wherein said drive means comprises at least one turbine.

7. A vehicle according to claim 6, wherein at least one said turbine is a multi stage turbine.

8. A vehicle according to claim 6 or 7, wherein the drive means further comprises at least one stator for altering direction of fluid flow to increase efficiency of transfer of energy from the fluid to at least one said turbine.

9. A vehicle according to any one of the preceding claims, wherein said connector means comprises a first part having at least one first cam groove and a second part having at least one cam projection adapted to engage at least one said first cam groove such that rotation of said shaft portion in a first sense causes at least one said cam projection to move along a said first cam groove to cause at least one said second surface engaging means to move away from said first surface engaging means.

10. A vehicle according to claim 9, wherein the first part further includes at least one second cam groove to cause at least one said second surface engaging means to move towards said first surface engaging means.

11. A vehicle according to claim 10, wherein the or each said first cam groove has a smaller pitch than the or each said second cam groove.

12. A vehicle according to claim 10 or 11, wherein at least one said first cam groove is connected to at least one said second cam groove, and at least one said cam projection is adapted to transfer between said first and second cam grooves to reverse the direction of travel of the first part relative to the second part.

13. A vehicle according to any one of the preceding claims, further comprising biasing means for urging at least one said second surface engaging means towards said first surface engaging means.

14. A vehicle according to any one of the preceding claims, further comprising at least one gearbox connected between said drive means and said connector means.

15. A vehicle according to any one of the preceding claims, wherein the vehicle is articulated.

16. A vehicle according to claim 15, wherein the vehicle is articulated rearwardly of said drive means in use.

17. A vehicle according to any one of the preceding claims, further comprising braking means for increasing the fluid drag of the vehicle.

18. A vehicle according to claim 17, wherein the braking means comprises at least one sealing means for sealingly engaging the internal surface of the conduit.

19. A vehicle according to any one of the preceding claims, further comprising one or more wheels for engaging the surface of the conduit.

20. A vehicle according to any one of the preceding claims, further comprising conduit inspection means.

21. A vehicle according to any one of the preceding claims, further comprising conduit repair means.

22. A vehicle for travelling along a conduit having fluid flowing therein, the vehicle substantially as hereinbefore described with reference to the accompanying drawings.



INVESTOR IN PEOPLE

Application No: GB 9923000.5
Claims searched: 1-22

Examiner: Dr Steve Chadwell
Date of search: 29 March 2001

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): B7H (HNF); E1F (FHJ, FKU); F2N; F2P (PG1)

Int Cl (Ed.7): B08B 9/04; F16L 55/30, 55/32, 55/34, 55/36, 55/38

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2350386 A (WEATHERFORD/LAMB)	
A	GB 2333341 A (UNIVERSITY OF DURHAM)	
A	GB 2305407 A (UNIVERSITY OF DURHAM)	
A	GB 2167829 A (BRITISH NUCLEAR FUELS)	
A	GB 0614592 (GANIN)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

THIS PAGE BLANK (USPTO)

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☒ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO)